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RF Note #055

YK1240 Klystron Performance Measurements For the Photo-Injector Laboratory Capture Cavity System

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Introduction

The Fermilab Photo-Injector Laboratory currently uses a Philips YK1240 to drive its superconducting capture cavity. Over the last year, the perveance of the installed klystron has been gradually decreasing, thus limiting the available output power. Two of the three YK1240 klystrons which had been kept in storage were evaluated for use in the capture cavity system. The third klystron was not in a condition to be tested since its electron gun assembly remains disconnected due to a previous maintenance analysis. Serial number (S/N) V108SK-7 exhibited the best performance and is now installed in the system. The performance measurements are presented here to aid in planning the system maintenance program.

Preparation & Measurement Setup

A YK1240, S/N V108SK-8, is shown in its cradle in Fig. 1. The far end contains the cathode and electron gun assembly while the near end is the collector. The output waveguide couples to the klystron output cavity through a vacuum window. The orange object is the klystron's vacuum ion-getter pump.

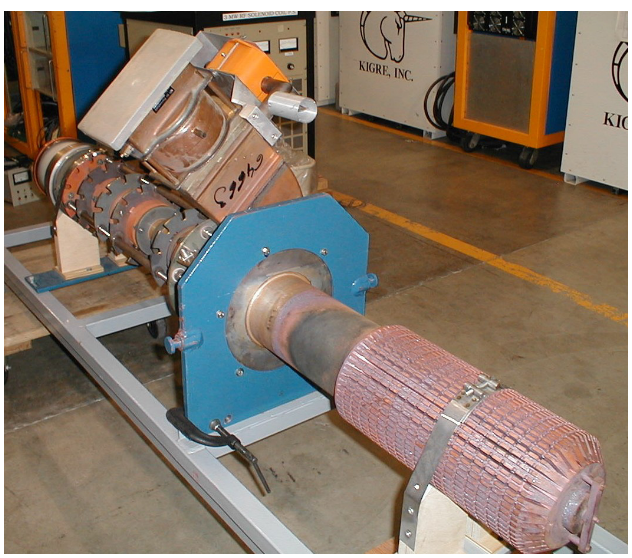


Figure 1: YK1240 S/N V108SK-8

A complete klystron mounted within the focusing solenoid and oil tank is shown in Fig. 2. A spare assembly tank had also been kept in storage and was taken out to build up a spare klystron assembly which was used for testing the klystrons that came out of storage. This spare tank has been labeled Tank #2 while the tank which was in use in the Photo-Injector system has been labeled Tank #1. The difference between Tank #1 and Tank #2 is that the fans on Tank #1 are wired for 208V operation while those on Tank #2 are wired for 120V operation. Tank #2 was filled with Diala oil AX.

For measurements, the system's klystron output waveguide was disconnected from the waveguide leading to the capture cavity inside the A0 South Cave and connected to a water cooled load on top of the cave. A simplified block diagram of the measurement setup is shown in Fig. 3. The signals at the input and output directional couplers were measured with a high frequency TEK7104 oscilloscope. The klystron collector to cathode potential and cathode current were measured at the modulator supply. The cathode heater power was measured at the heater supply. The solenoid current was kept at the typical operating level of 12A.

Figure 2: Complete klystron assembly in solenoid and oil tank

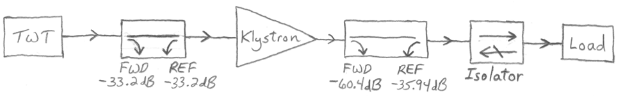


Figure 3: Simplified Measurement Block Diagram

Performance Measurements

The YK1240 datasheet indicates the typical operating conditions and performance shown in Table 1.

Table 1: YK1240 Datasheet Typical Performance

Cathode Heater Power (W)	250
Solenoid Current (A)	12
Cathode Voltage (KV)	-60
Cathode Current (A)	11
DC Input Power (KW)	660
Input RF Power (KW)	0.027
Output RF Power (KW)	325
Gain (dB)	40.8
Efficiency (%)	49
Pulse Length (s)	1.5
Duty Factor	0.005

Serial No. V108SK-2

The klystron which had been used in the system since April of 1995 was S/N V108SK-2. One of the last measurements of the maximum output power of this klystron at increased heater power is shown in Table 2. Not all of the coupling ports of the system had been calibrated at the time of this measurement; therefore, no accurate results could be determined about the RF input power or the gain of the klystron. The output power was indirectly measured from a forward power measurement at the capture cavity and extracting out the loss of approximately 121 feet of WR-650 waveguide between the klystron and the capture cavity input directional coupler.

Table 2: YK1240 S/N V108SK-2 Measurement taken on 12/3/2002

Heater Primary Voltage (V_{RMS})	239
Heater Primary Current (A_{RMS})	1.09
Cathode Heater Power (W)	262
Solenoid Current (A)	12
Cathode Voltage (KV)	-60
Cathode Current (A)	5.38
DC Input Power (KW)	323
Max. Output RF Power (KW)	74

Serial No. V108SK-8

The first klystron from storage that was tested was S/N V108SK-8, which originally ran in the PI system for 17 months prior to the installation of V108SK-2 [4]. Upon initial turn on of the heater, there was some expected out-gassing indicated on the vacuum ion-getter pump supply. The initial pressure level indicated was a few 10^{-6} torrs. Within approximately 3 hours at full heater power the pressure level recovered to less than 10^{-8} torr. By the time the klystron was operated with RF, the supply reading was at its minimum indicating level of $3 \cdot 10^{-9}$ torr.

A corona ring was machined to fit onto the cathode where the electron gun is sealed to the ceramic insulator. It was unclear whether the original klystron had or even needed a corona ring at this location which is submersed in oil, thus one was used as a precautionary measure.

The klystron was tested up to the point of saturating its RF output power level. Measurement data can be found in Appendix A. The maximum output power of V108SK-8 was approximately 100KW.

Serial No. V108SK-7

The second klystron from storage that was tested was S/N V108SK-7. It was tested in the same tank assembly, Tank #2, in which V108SK-8 was tested. The custom cathode corona ring did not allow V108SK-7 to sit properly in the cathode socket, thus it was abandoned. V108SK-7 was measured to be approximately ¼" longer than V108SK-8 from the cathode to the klystron seating flange. It performed well without the corona ring and with no indications of problems from its absence. It also exhibited initial vacuum behavior similar to V108SK-8.

Measurement data can be found in Appendix A. The achieved maximum output power of 192KW was limited by a combination of saturation of the klystron and saturation of the low-level RF drive.

Serial No. V108SK-4

A fourth klystron exists and still remains in Beams Division storage. Its electron gun assembly had been removed and inspected during a previous failure analysis by Communications & Power Industries (CPI). The gun remains separated from the klystron body and can be found in the same storage container.

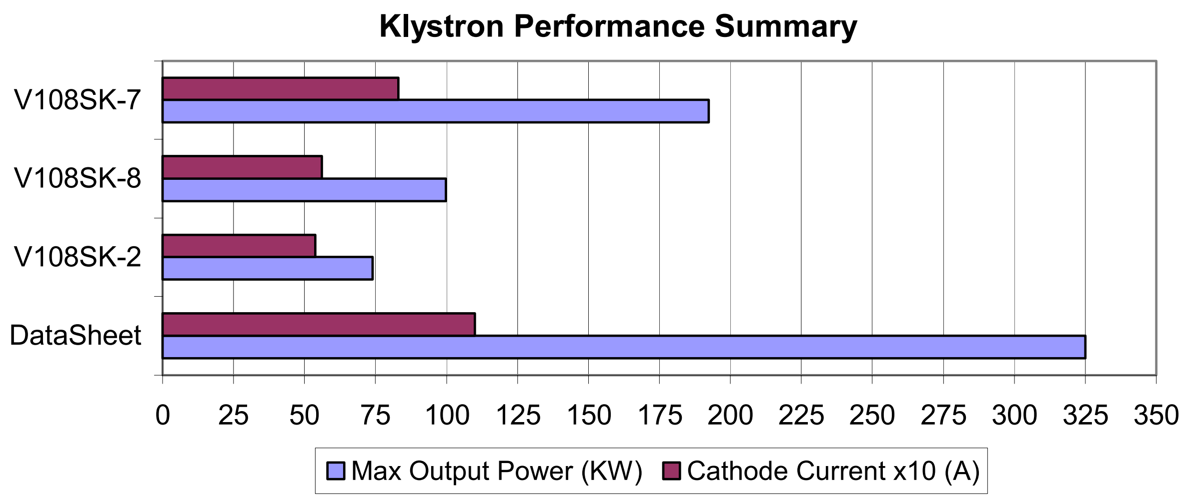


Figure 4: YK1240 Performance Measurements Summary. V108SK-4 was not in a condition to be tested.

Summary

The results of the performance measurements are summarized in Fig. 4. Clearly V108SK-7 is the best YK1240 klystron available to the Photo-Injector. It is now installed in the system within Tank #2 and is successfully being used to drive the capture cavity.

A few comments concerning the status of parts need to be made. A set of caps for covering the klystron body cavity coupling ports is missing. A split retaining ring to constrain the topmost solenoid was missing from Tank #2. The one from Tank #1 was removed and used on Tank #2 for installation. There are 3 collector water cooling jackets. Two are being used, one for each tank assembly. A third is being stored in an RF component cabinet at A0 at this time.

Clearly, all of the tested klystrons do not measure up to the datasheet specifications. From [3] measurement data from VALVO Philips was obtained on V108SK-2 and V108SK-7. In June of 1982, V108SK-2 was able to produce 320KW. In August of 1983, V108SK-7 was able to produce 335KW (see Appendix B for some detailed data).

V108SK-4 and V108SK-7 came to Fermilab from DESY via CPI [3]. Before V108SK-7 came to DESY it had only 510 filament hours on it. It was never operated at DESY.

V108SK-8 ran for a total of 17 months of filament time, mostly at red heat before it was replaced with V108SK-2 [4]. V108SK-8 initially produced 120KW peak at a cathode voltage of -54KV. Two months later, it only produced 80KW and continued here for 12 months. At the time of replacement, its peak output power was 59KW at –50KV cathode voltage and 5.4A cathode (beam) current. V108SK-2 was commissioned in the PI on April 17, 1995. It initially produced 100KW at –50KV cathode voltage and 7.2A cathode (beam) current.

The information provided here along with the knowledge of a disassembled V108SK-4 can be used to develop a system maintenance, rebuild, and/or upgrade plan.

References

[1] Philips YK1240 Datasheet

[2] Private communication with Chris Jensen

[3] Private communication with Stefan Choroba from DESY

[4] email correspondence between Karl Koepke of Fermilab and Stefan Choroba of DESY.

[5] T.Berenc, “Calibration of the RF Power Monitors for the Photo-Injector Laboratory RF System”, Fermilab RF Note #044, 27 Aug 2002, <http://www-rfes.fnal.gov/global/technotes/TN/TN044.pdf>

Appendix A

YK1240 S/N V108SK-8
Measurement Data
Taken 6/4/2003

Experimental Operating Conditions	Primary Heater Voltage (V_{RMS})	211
	Primary Heater Current (A_{RMS})	1.23
	Cathode Heater Power (W)	262
	Cathode Voltage (KV)	-58.6
	Cathode Current (A)	5.6
	DC Input Power (KW)	328

Klystron RF Input Power	FWD Power (W)	13	30	45
	REF Power (W)	0.5	1.1	1.7

Klystron RF Output Power	FWD Power (KW)	62.0	95.3	99.7
	REF Power (KW)	0.37	0.43	0.45

Performance	Gain (dB)	36.9	35.1	33.5
	Efficiency (%)	19	29	30

YK1240 S/N V108SK-7
Measurement Data
Taken 6/12/2003

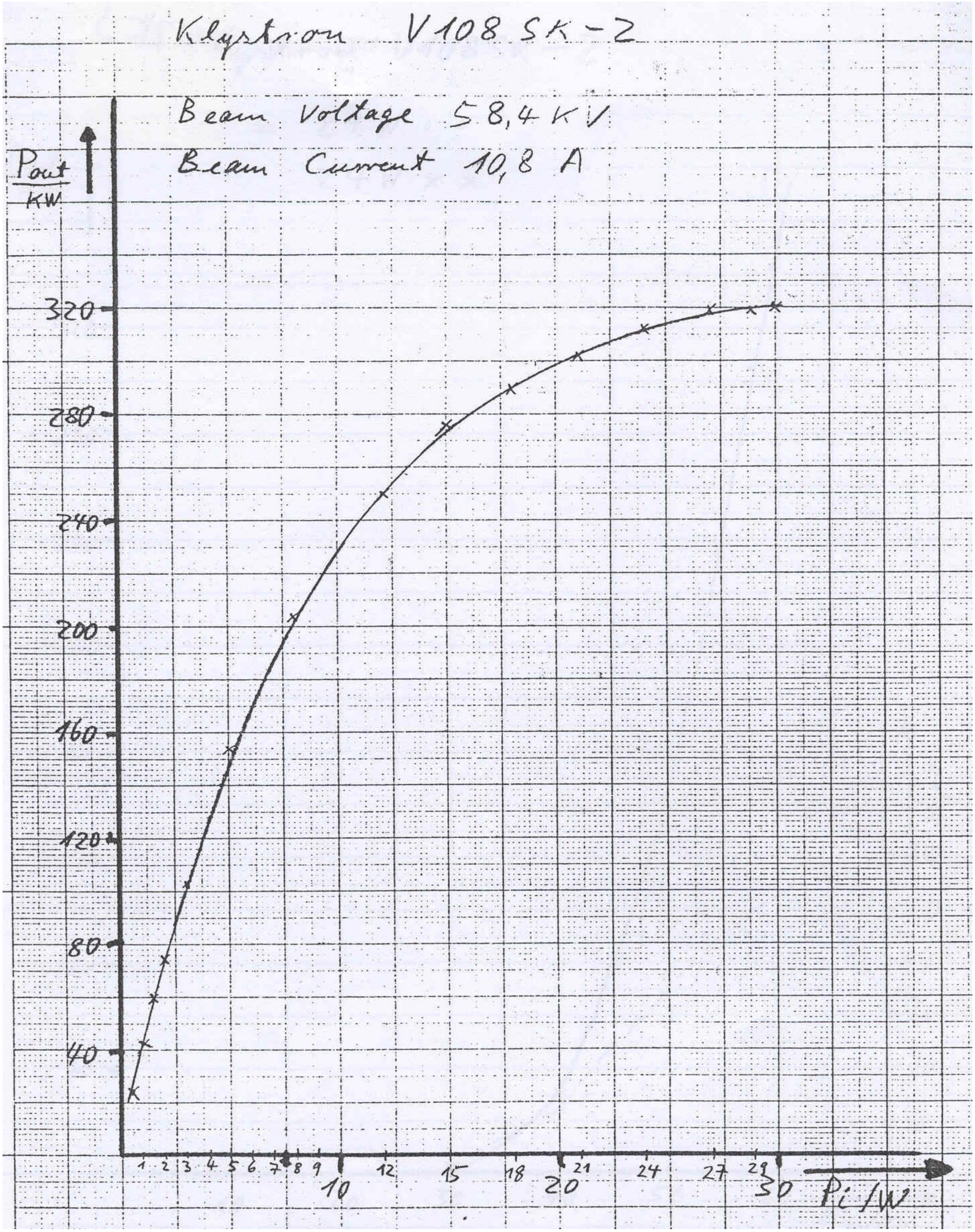
Experimental Operating Conditions	Primary Heater Voltage (V_{RMS})	208
	Primary Heater Current (A_{RMS})	1.23
	Cathode Heater Power (W)	257
	Cathode Voltage (KV)	-58.9
	Cathode Current (A)	8.3
	DC Input Power (KW)	489

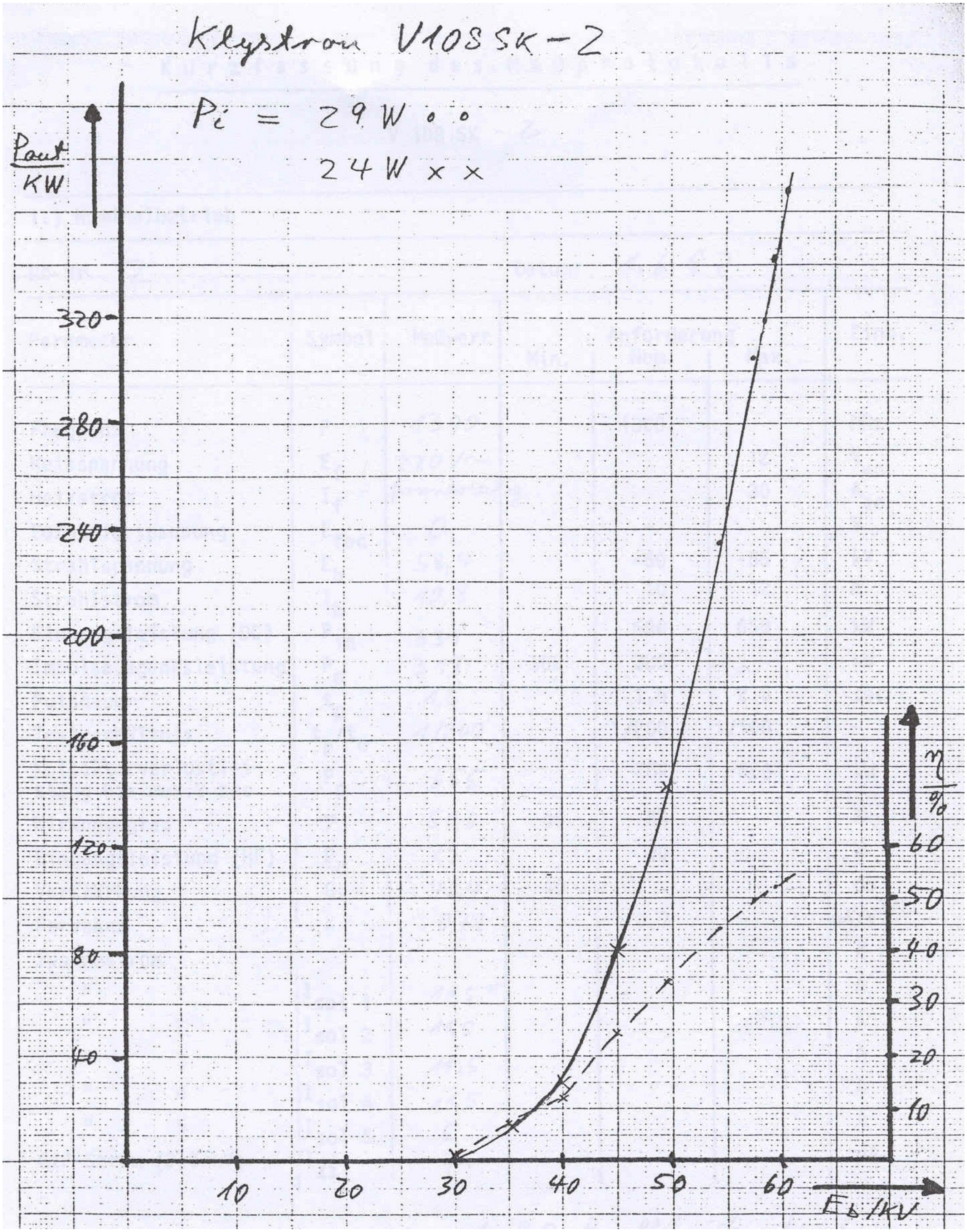
Klystron RF Input Power	FWD Power (W)	3	6	8	11	14	15	17
	REF Power (W)	0.2	0.6	0.8	1.0	1.2	1.4	1.7

Klystron RF Output Power	FWD Power (KW)	60.3	111.1	133.1	154.4	171.3	183.2	192.3
	REF Power (KW)	0.32	0.53	0.65	0.74	0.80	0.86	0.91

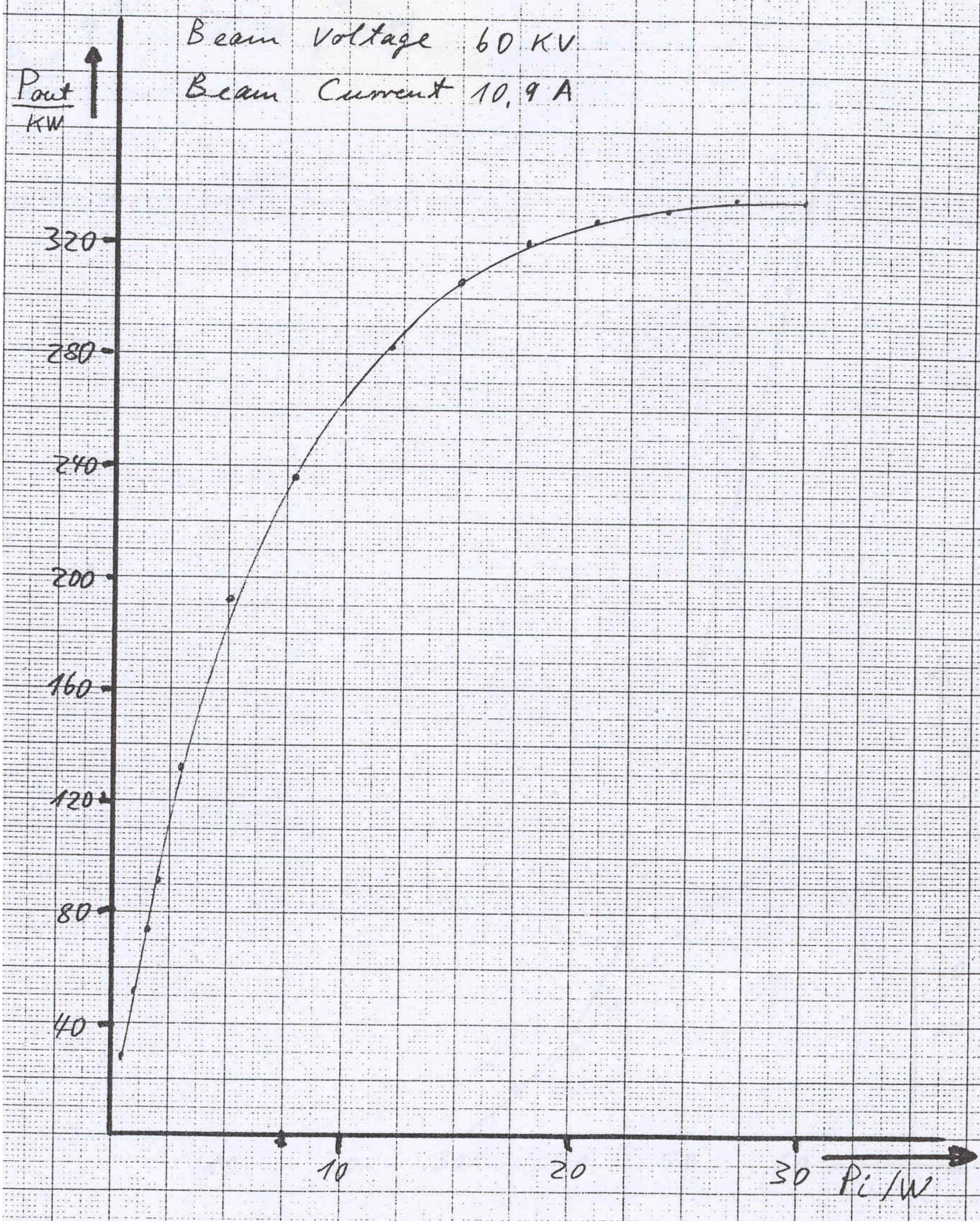
Performance	Gain (dB)	43.1	42.7	42.2	41.5	40.9	40.9	40.5
	Efficiency (%)	12	23	27	32	35	37	39

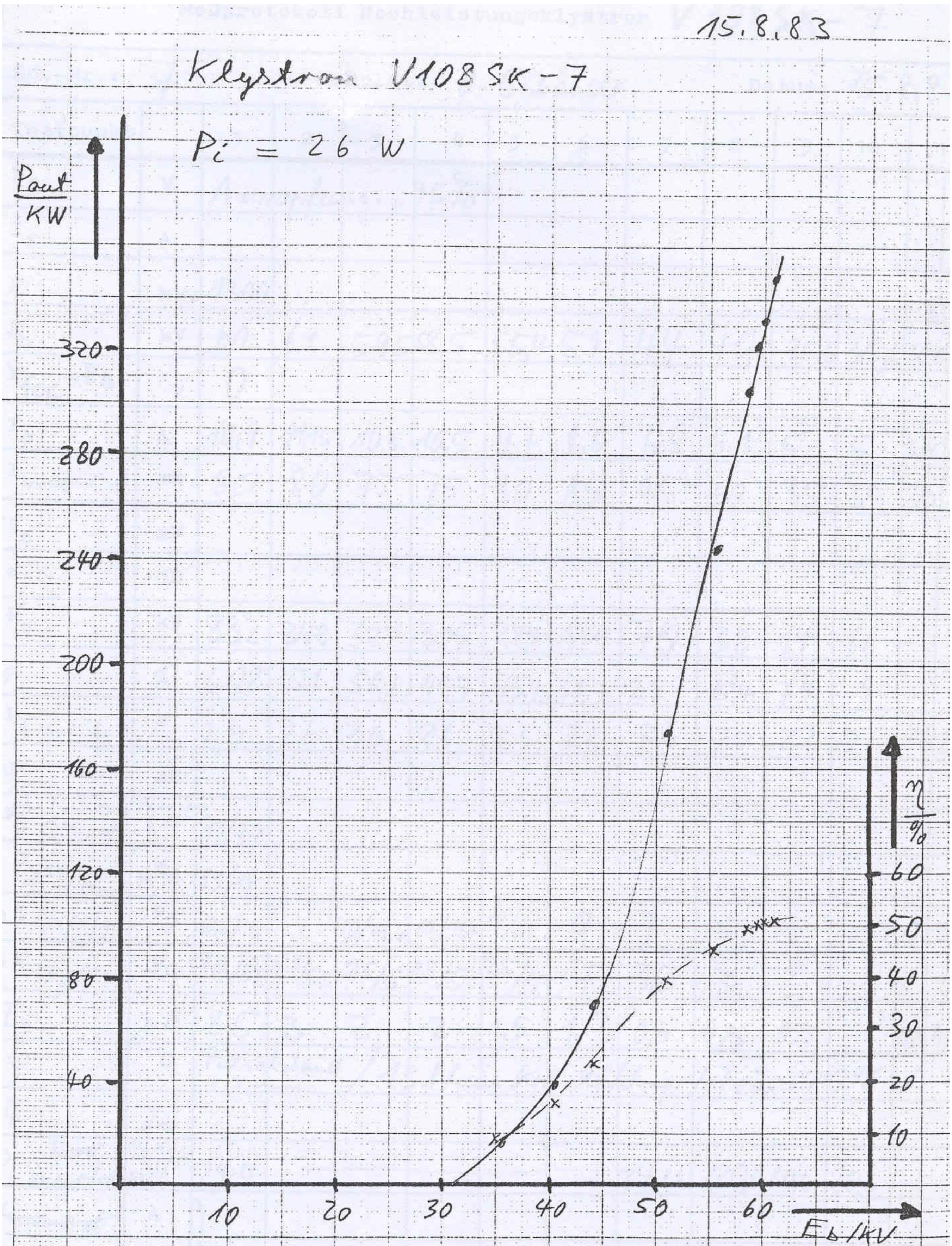
Appendix B
Early Data on V108SK-2 (circa 1982) and V108SK-7 (circa 1983)




Klystron V10SSK-Z
Pi = 29W ∘ ∘
24W × ×
Pout / KW
320
280
240
200
160
120
80
40
η / %
60
50
40
30
20
10
10
20
30
40
50
60
Eb/KV

Klystron V108 SK-7 15.8.83





15.8.83
Klystron V108 SK-7
Pi = 26 W
Pout / KW
320
280
240
200
160
120
80
40
η / %
60
50
40
30
20
10
10
20
30
40
50
60
Eb / KV